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Author:

Howell, Joe

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S6. Near-term Demonstrators and Experiments

Co Authors:

Howell, Joe O'Neill, Mark Fork, Richard

Abstract Title:

Advanced Receiver/Converter Experiments for Laser Wireless Power Transmission

Abstract Text

For several years NASA Marshall Space Flight Center, UAH and ENTECH have been working on various aspects of space solar power systems, some of which include four process elements:

- (1) space solar radiation collection and conversion to electrical power
- (2) conversion of this electrical power to laser radiation
- (3) wireless power transmission of this laser radiation to an end-use location
- (4) collection of the laser radiation and conversion to electrical power

Early studies and prototype experiments showed that photovoltaic concentrator technology could provide significant performance, cost, and mass benefits for the first process element, the solar collector/converter. Solar concentrator arrays have already demonstrated net solar-to-electric conversion efficiencies of 28% at room temperature, and technology roadmaps anticipate solar concentrator array efficiencies over 50% within the next two decades. Furthermore, the specific power of solar concentrator arrays should move from 180 W/kg today to over 1,000 W/kg during the next two decades. Most importantly, solar concentrator arrays are far more cost-effective than conventional planar photovoltaic arrays, because they replace expensive semiconductor material (the solar cells) with much lower cost Fresnel lenses, which collect and focus the sunlight onto small cells, saving 85% or more of the cell area per Watt of power produced.

More recently, studies have indicated that photovoltaic concentrator technology could likewise provide significant performance, cost, and mass benefits for the fourth process element, the laser receiver/converter, which

could be located on Earth, on another celestial body (e.g., the Moon or Mars or asteroids or comets), or on a spacecraft, depending on the application. As proof of concept experiment, a small prototype photovoltaic concentrator has recently been built and tested under laser illumination. The prototype includes a silicone mini-dome Fresnel lens, which collects and focuses laser radiation onto a GaAs single-junction photovoltaic cell. The geometric concentration ratio (lens aperture area divided by cell active area) is about 86X for this prototype. Equipped with a prismatic cell cover to eliminate metal gridline shadowing loss, the photovoltaic cell is mounted onto a thin carbon composite radiator for waste heat rejection. Under continuous 0.81-micron-wavelength laser input (0.26 W), the mini-dome-lens GaAs-cell prototype has already demonstrated over 52% net laser-to-electric conversion efficiency in a room-temperature laboratory environment.

The current activity was just begun in January 2004 to further develop this new photovoltaic concentrator laser receiver/converter technology. During the next few months, an improved prototype will be designed, fabricated, and thoroughly tested under laser illumination. Substantially higher efficiencies than the 52% mentioned above are anticipated for the improved prototype. Results from the improved prototype testing should be available in time for presentation in the final paper for SPS04.

The final paper will describe the new concept, present its advantages over other laser receiver/converter approaches (including planar photovoltaic arrays), and provide the latest experiment results on prototype hardware (including the effects of laser irradiance level and cell temperature). With NASA's new human exploration plans to first return to the Moon, and then to proceed to Mars, the new photovoltaic concentrator laser receiver/converter technology could prove to be extremely useful in providing power to the landing sites and other phases of the missions. For example, to explore the scientifically interesting and likely resource-rich poles of the Moon (which may contain water) or the poles of Mars (which definitely contain water and carbon dioxide), laser power beaming could represent the simplest means of providing power to these regions, which receive little or no sunlight, making solar arrays useless there.

In summary, the authors propose a paper on definition and experimental results of a novel photovoltaic concentrator approach for collecting and converting laser radiation to electrical power. The new advanced photovoltaic concentrator laser receiver/converter offers higher performance, lighter weight, and lower cost than competing concepts, and early experimental results are confirming the expected excellent performance levels. After the small prototypes are successfully demonstrated, a larger array with even better performance is planned for the next phase experiments and demonstrations. Thereafter, a near-term flight experiment of the new technology should be developed and flown, to lay the groundwork for future space power applications in the Earth-Moon neighborhood, and ultimately encompassing Mars and its environs.